MultiPARTES: Virtualization of Heterogeneous Multicore

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SEVENTH FRAMEWORK PROGRAMME

MultiPARTES FP7 Project

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MultiPARTES Project

- **Objective: Support mixed criticality systems based on heterogeneous multicore open source virtualization**
- Project details
  - IKERLAN-IK4 Project coordinator
  - 2.850.000 Euro EC Contribution
  - Sep 2011 / Aug 2014 Project start / end date
  - 36 months Duration
- Web: http://www.multipartes.eu/

MultiPARTES Goals

1) MultiPARTES **aims at developing tools and solutions based on mixed criticality and assurance-based virtualization systems for multicore.**
The starting point for virtualisation support is **XtratuM**, an open source cost-effective hypervisor.

2) MultiPARTES will offer a **rapid and cost-effective development of trust real-time embedded systems** sharing critical and no critical applications the system resources.

MultiPARTES Topics

- **Aim: Support mixed criticality systems based on heterogeneous multicore open source virtualization**

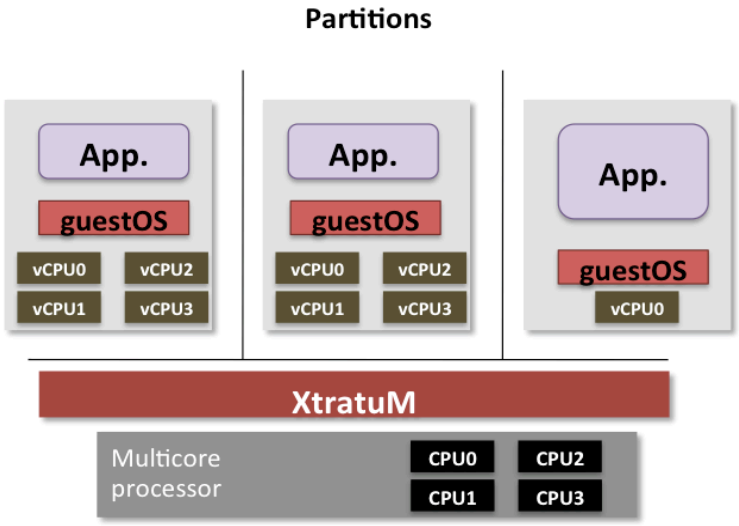
- **Multicore Virtualization**
  - Uniform view for partitions
  - AMP / SMP XtratuM hypervisor
- **Heterogeneity**
  - Hardware platform with different processors
  - Software architecture
  - Communication & synchronization between cores
- **Mixed criticality => Methodology and Tools**
  - System definition models: Platform, Computational, …
  - Criteria to allocate functions to partitions
  - Scheduling tool

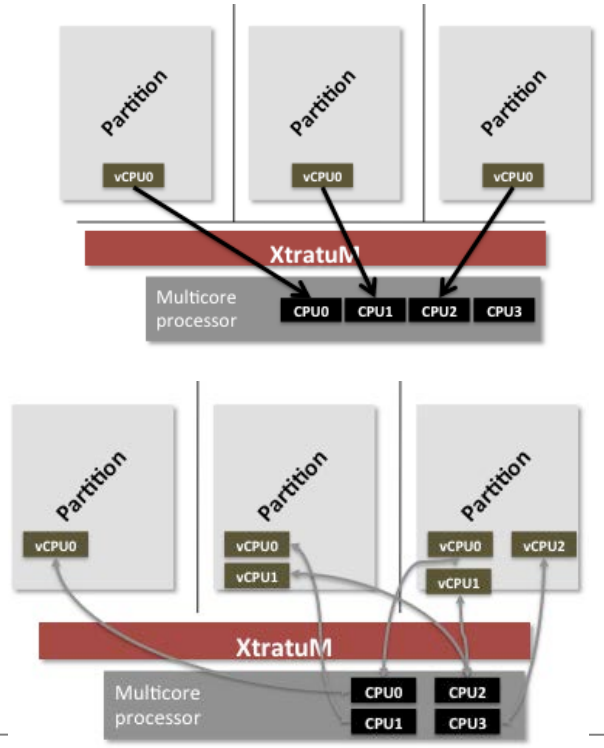
Multicore Virtualization

- **Based on XtratuM Multicore**

  (proof of concept in SIDMS ESA project)

  - Offers as many *virtual CPUs* as real CPUs are in the board
  - Initialises the real CPUs and offers the *virtualCPU*0 to the partitions
  - Partitions are in charge of initializing other *virtualCPUs*
  - Partitions can be mono-core or multicore





Multicore Virtualization

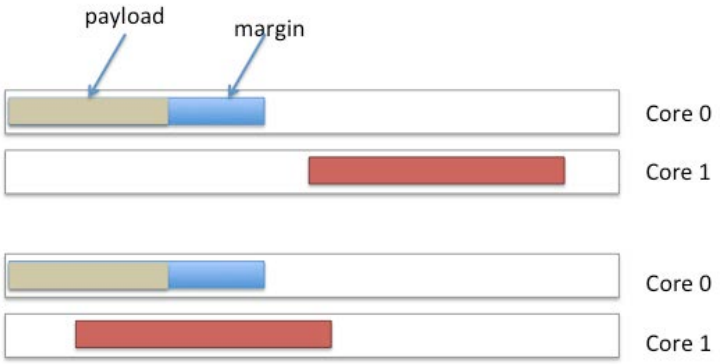
- **Temporal and Spatial Partitioning systems**
  - **Temporal isolation**
    - Temporal allocation of partitions
    - **Execution Interference of other cores**
  - Spatial isolation
    - No additional problems
  - Shared resources:
    - Cache L2 and L3, bus arbitration, memory
    - Introduce unpredictable execution time in partitions

Multicore Virtualization

- **Worst Case Execution Time Impact**

$$WCET = WCET_{task} + Interference$$

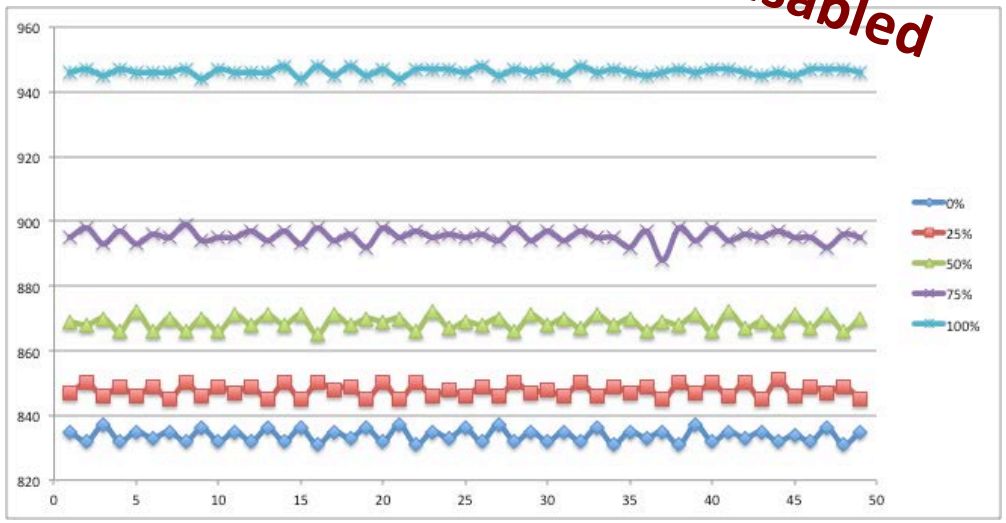
  - **The interference can be modeled**
    - **Evaluating the Inteference**
    - **Limiting it by construction of the scheduling plan**



	S25	S50	S75	S100
Interference	1,68%	4,20%	7,31%	13,43%

Atom Dual Core@ 1666MHz

Atom Dual Core
Cache disabled



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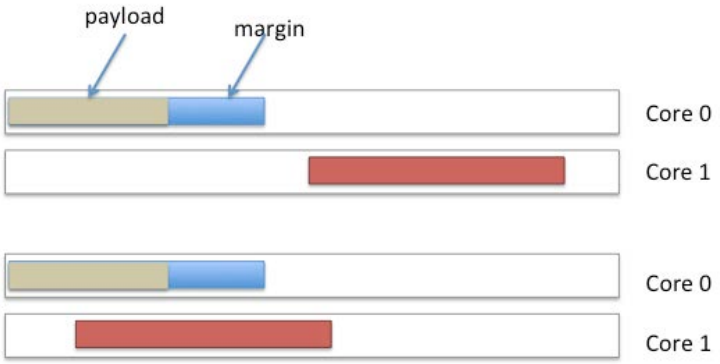
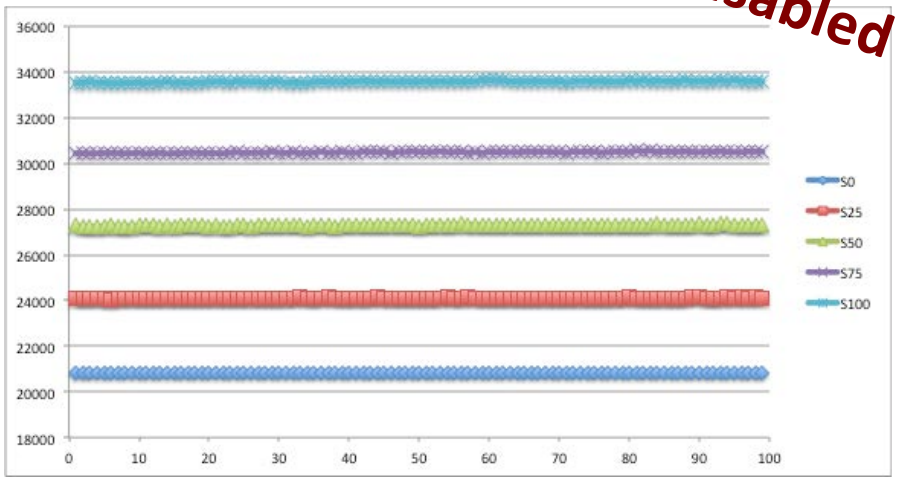


	S25	S50	S75	S100
Interference	15,74%	31,05%	46,39%	61,22%

LEON3 @ 50MHz

LEON3 platform
Cache disabled



Heterogeneity

- **Integration of different hardware platforms** permits:
  - Hardware diversity
  - Specialized hardware
  - Isolation of critical => deterministic hardware
- **MultiPARTES**:
  - 1 Atom Dual Core + FPGA with 2 LEON3 with shared memory
- Examples
  - Space: LEON3 Multicore + ARM Cortex processor
  - Space: LEON3 Multicore + DSP

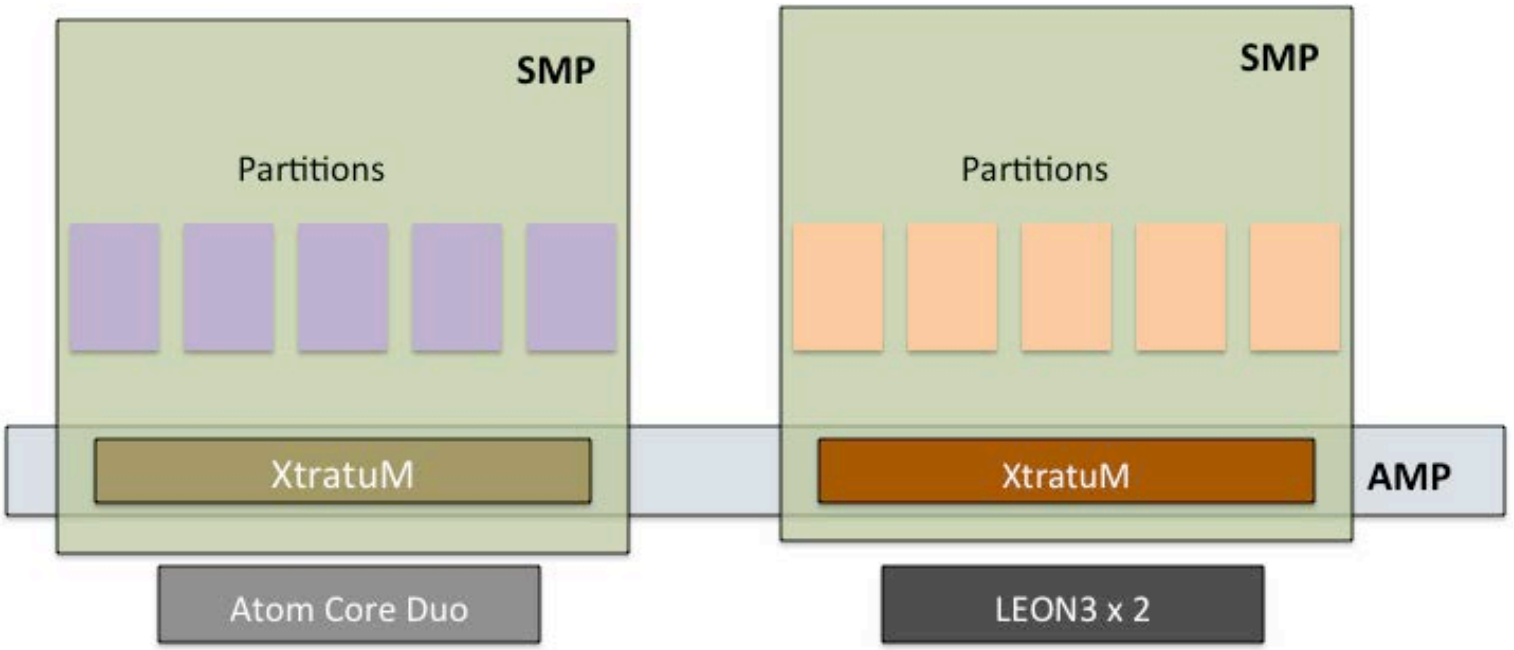
Heterogeneity: Software Arch.

ASM: Asymmetric multiprocessing

- Each core is handled by one OS instance

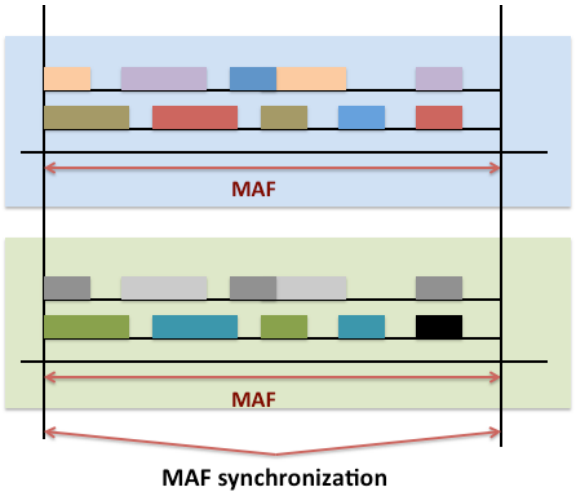
SMP: symmetric multiprocessing

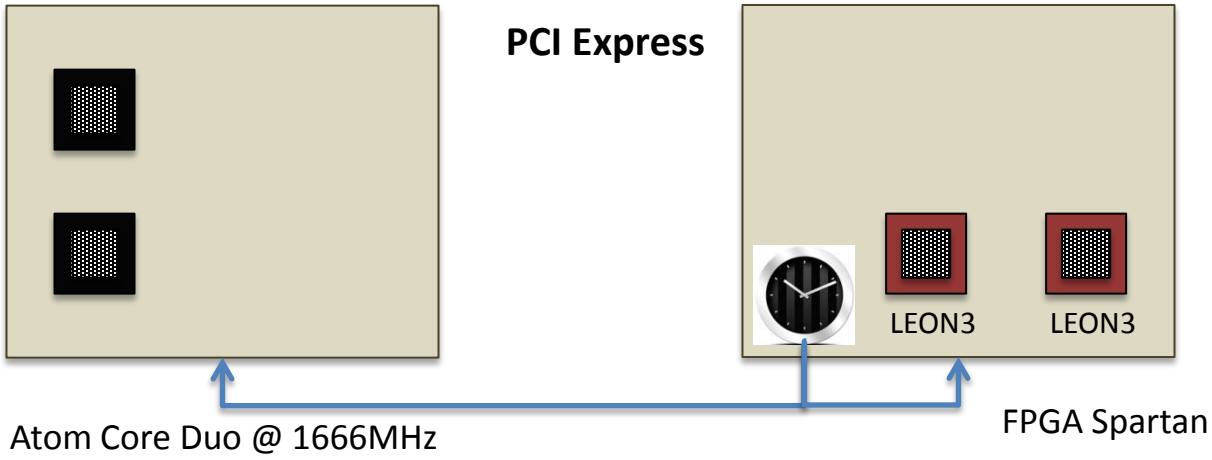
- All cores are handled by the OS



Heterogeneity

- Needs
  - **Clock synchronization: MAF synchronization**
  - Inter-partition/Inter-platform communication
    - Double port memories
    - Bus based communication





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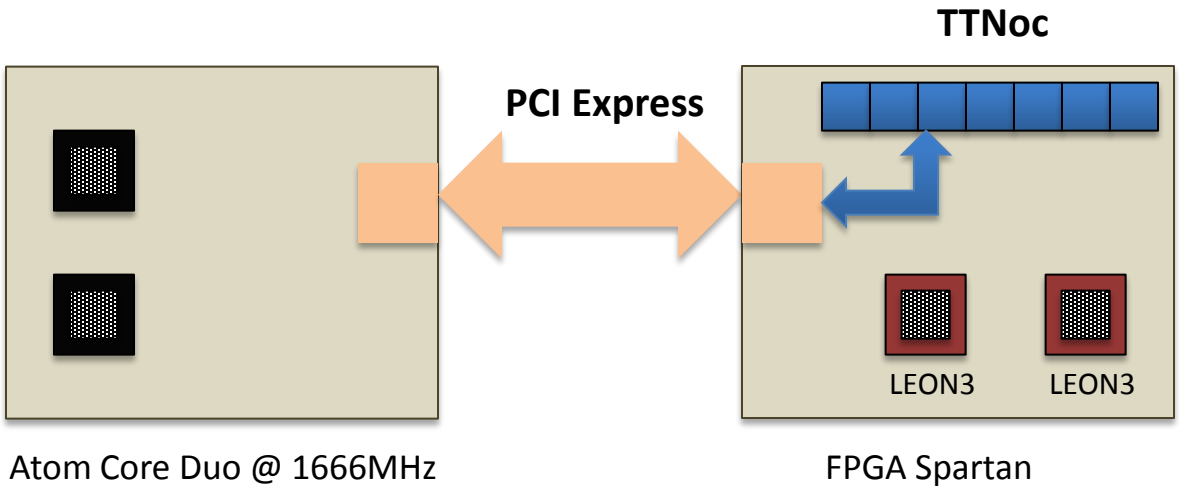


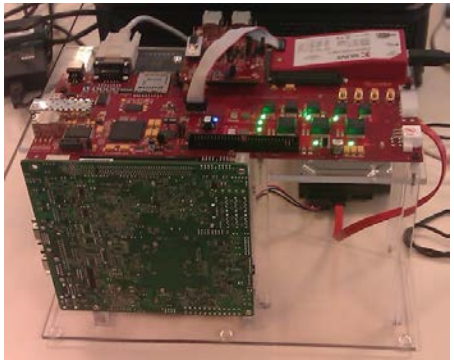
Heterogeneity: Sw

- Execution Environments
  - **MTPAL: MultiPARTES Abstraction Layer. Single thread applications. Basic services (TSAL IMA-SP)**
  - **PartiKle: Real-time kernel. POSIX PSE51.**
  - **ORK+: Ada applications. Ravenscar Profile.**
  - **Linux**

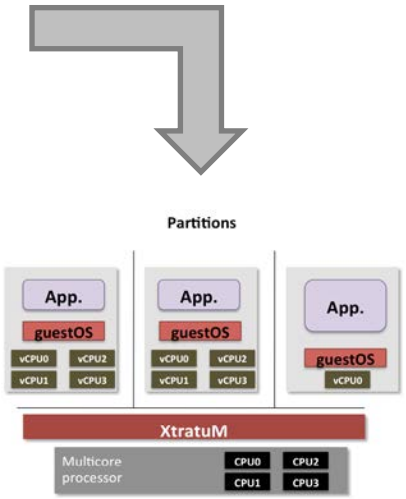
	LEON3	x86
MTPAL	x	x
PartiKLe	x	x
ORK+	x	
Linux		x

	License
MTPAL	GPL
PartiKLe	GPL
ORK+	GPL
Linux	GPL

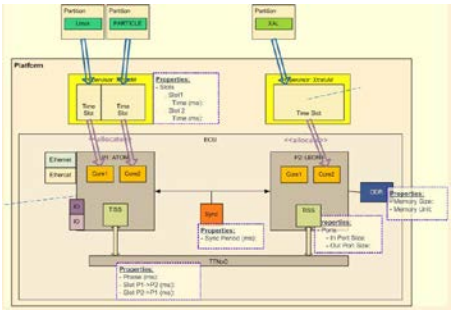
Model-driven Partitioning



Real world



Abstraction



Modeling tool

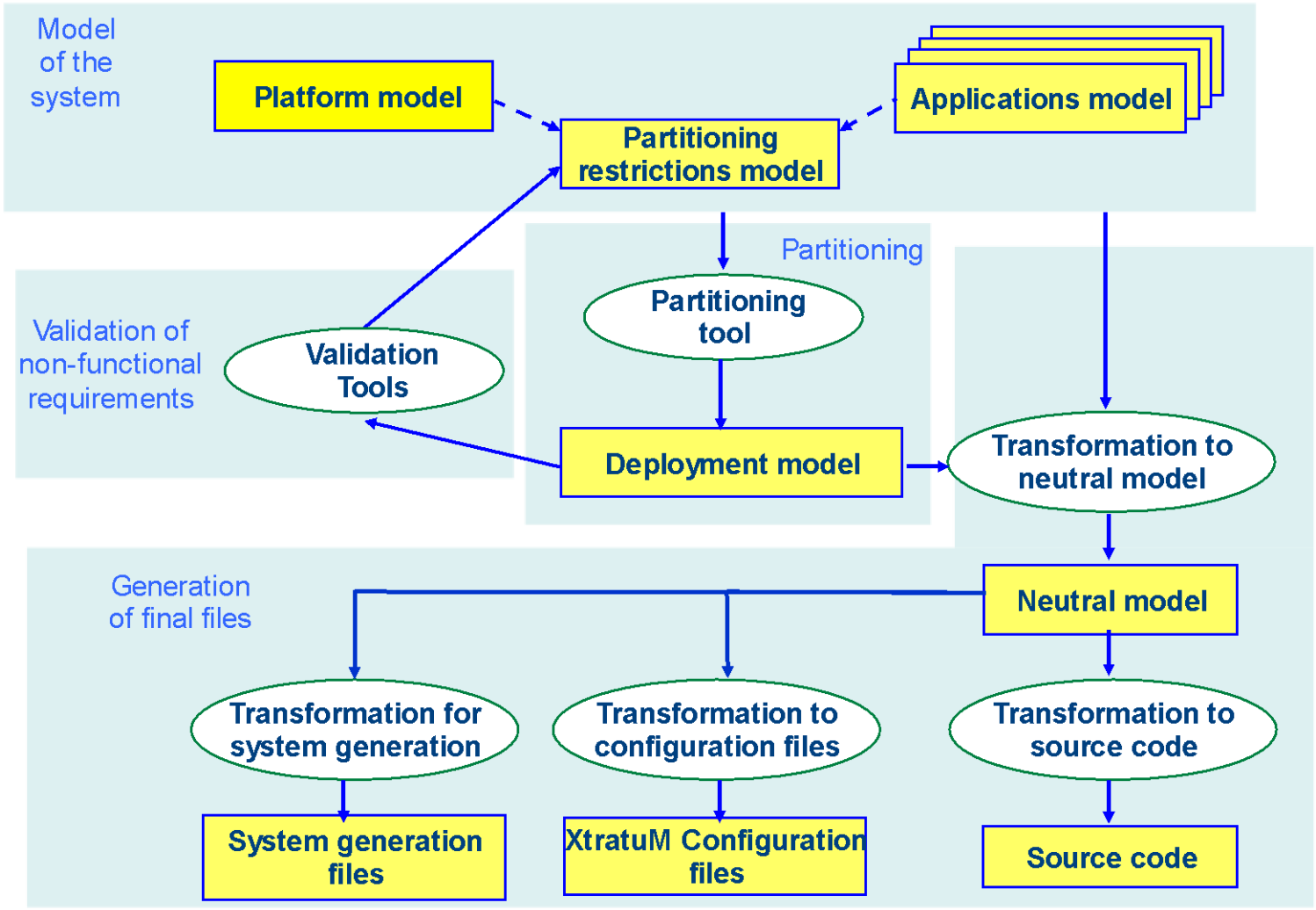
```
bool Custom_nodeAppImpl::init()
{
    icAcquireInputs = new Custom_nodeAcquireIn
    nvVote_inputs = new Custom_nodeVote_inputs
    fbOdometry = new Custom_nodeOdometry();
    fbMode_control = new Custom_nodeMode_contr
    nvVote_odometry = new Custom_nodeVote_odom
    fbBrake_curve_generator = new Custom_nodeB
    fbDecide = new Custom_nodeDecide();
    fbStand_by = new Custom_nodeStand_by();
    nvVote_outputs = new Custom_nodeVote_outpu
    ocWrite_outputs = new Custom_nodeWrite_out
}
```

Generated artifacts

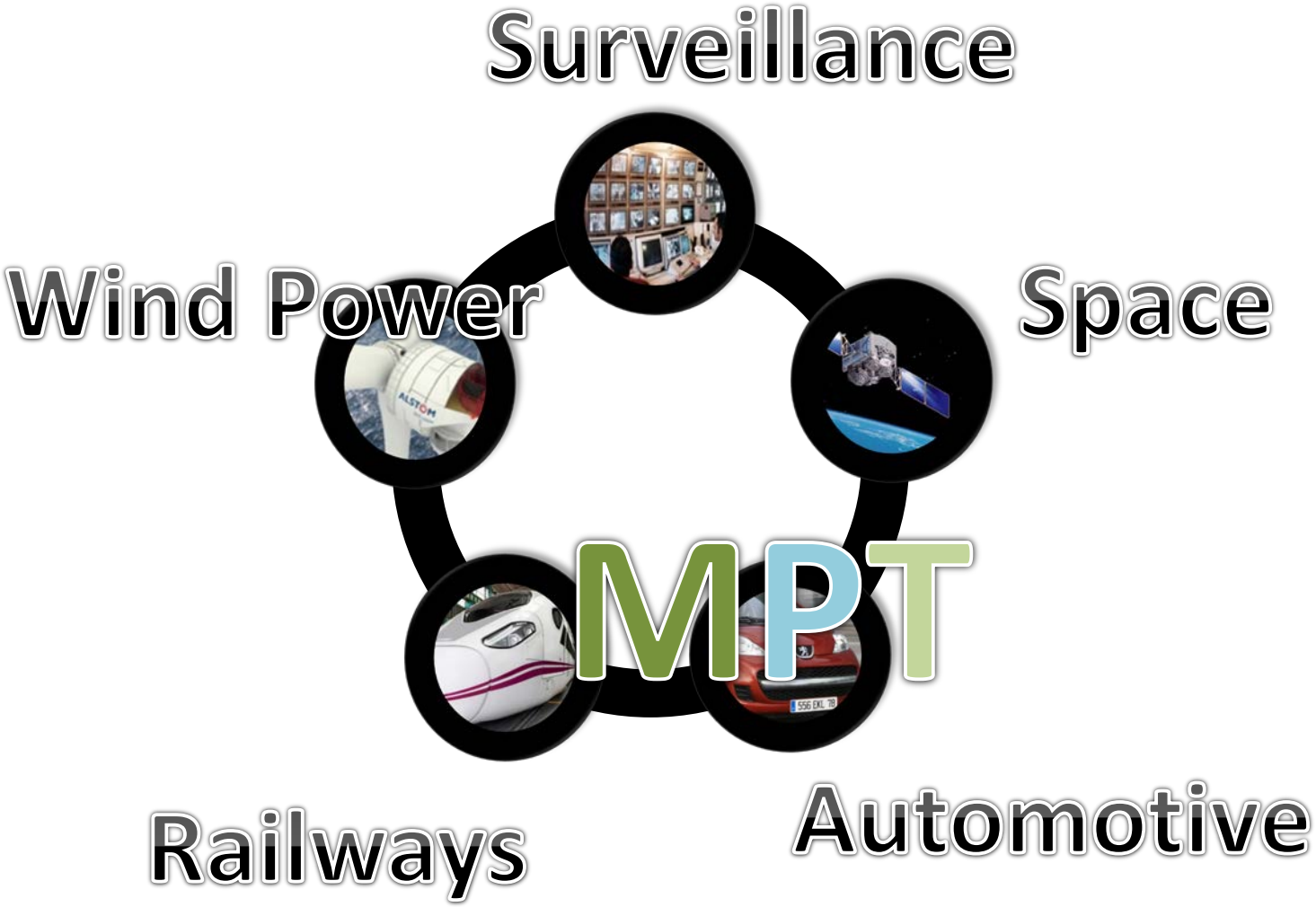
Input / Activities / Output

- Input information:
  - Platform and Application models
  - Partitioning restriction model
- Activities:
  - Propose a system partitioning
  - Meet the real-time, safety and security constraints
- Outcomes:
  - Code skeletons, XtratuM configuration files, make file

Architecture of the toolset



Industry demonstrators



Industry demonstrators

- Video surveillance
  - X86 platform
  - MTPAL, PartiKle, Linux
  - Devices: Video cameras, data storage
- WindPower
  - x86 and LEON3 platforms
  - MTPAL, Partikle and Linux
  - Devices: Scada system, EtherCAT,
  - IEC 61508 Pre-certification
- Space
  - LEON3 platform
  - MTPAL and ORK+
  - UPMSat Platform ADCS, OBDH, Communications, Payload

Project results

- Virtualization Layer
  - XtratuM Multicore for x86 and LEON3
- Execution Environments
  - Several guestOSs have been adapted
- Methodology
  - Model-driven. Application and design levels.
  - Partitioning, Scheduling, Code Generation Tools
- Hardware issues
  - Experimentation with TTNoC
  - Experimentation in mechanisms to reduce the memory interference

Current Status

- Virtualization Layer
  - XtratuM Multicore for x86 and LEON3
- Execution Environments
  - Several guestOSs have been adapted

Completed

- Methodology
  - Model-driven. Application and design levels.
  - Partitioning, Scheduling, Code Generation Tools
- Hardware issues
  - Experimentation with TTNoC
  - Experimentation in mechanisms to reduce the memory interference

On going

Certification aspects

- Wind power safety concept based on MultiPARTES multicore partitioning
  - Following IEC-61508
  - Presented to TÜV Rheinland
  - Positive feedback collected
  - TÜV report (under progress)
- Follow-up work in the context of DREAMS project

Benefits for Industry (Space)

- XtratuM has been evolved based on Space requirements
  - Maturity increased
  - Reusable Test suites
- Additional execution Environments
  - MTPAL: multicore evolution of TSAL (ESA IMA-SP project)
  - ORK+: developed under ESA contracts.
- Methodology
  - Partitioning criteria
  - Partitioning, Scheduling, Code generation tools
  - Hypervisor partitioning configuration generation
- Hardware
  - LEON3 multicore experimentation

Conclusions

- Snapshot halfway of the project
- Challenging field with industrial interests (there is some competition going on …)
- Collaborative effort together with other projects
- Transferring advance technology to the industry
- A new line of embedded systems is being conceived

- Beyond our project
  - From multi-core to many-core … does it make sense in industry? Where?
  - Certification of the approach. Work together with certification body?
  - Availability of commercial HW, HW mechanisms
  - Ease integration of legacy code

Thanks for your attention

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